Study of RPC Glass and Spacer Parameters

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What are the stress and deflections in the glass, spacers and adhesive for a range of glass thickness, spacer pitch and gas pressure? Increased spacer pitch would increase efficiency and would reduce assembly effort. Increased glass thickness would make sheets easier to handle and would reduce deflection. Increased internal design pressure would make the gas pressure control less critical.

Input data

- Belle used 2 mm glass with 150 mm spacer pitch (Kazuo Abe)
- Belle observed adhesive failure at 2 inches of water pressure in some locations. (Kazuo Abe)
- Belle did not analyze the chamber design but rather tested some samples to failure. (Kazuo Abe)
- Material is flat glass per ASTM C1036
- Modulus of Elasticity is 10e6 psi (Byars and Snyder)
- Tensile strength is 10e3 psi (Byars and Snyder)
- Maximum allowable stress 1000 psi (Wands recommendation) Since glass strength is strongly dependant on defects, even this might be too high.
- Spacer width 2 mm
- Coulomb force equivalent to 0.44 inches of water (Stan Orr)
- Calculations made for the ASTM minimum thickness for any nominal size
- Thicknesses available are 2.5 through 12 mm from PPG. Other suppliers have thicker glass. (Mike Ibideris of PPG Industries, 412-820-8500)
- The size 96 x 112 inches is not a problem to make. (Mike Ibideris)
- The capacity to make 80,000 sheets 6mm thick is not a problem. It is twemty-five days run time for one line. They have many lines. (Mike Ibideris)
- In this size any thickness less than 6mm will be difficult to handle and high breakage rate should be expected. (Mike Ibideris)
- The thickness tolerance is per ASTM C1036. Typically it is within 0.03 mm. (Mike Ibideris)
- There is no flatness standard since glass is easily bent by the support frame. (Mike Ibideris)

- Sheets this size would be difficult to handle in less than 5mm thickness. (Torstenson Glass, 773-525-0435)
- Glass usually shipped in 4000 lb crates. (Torstenson)
- Glass sheets must be handled vertically on edge unless vacuum fixture spreads out weight. (Torstenson)
- Thinnest available is 2.5 mm. (Torstenson)
- Calculations were made to find the deflection, bending stress and adhesive tensile stress for a range of glass thickness, spacer pitch and internal pressure. The calculations were simple beam bending equations for fixed end beams, ignoring end effects.
- Belle used 2 mm glass for space constraints. Thicker glass is not detrimental to detector operation. (Para)
- Spacers extend to within 100 mm of the edge of the plates.
- Standard glass thicknesses per ASTM C1036
    - 2mm nominal, min 1.80mm, max 2.13mm
    - 3mm nominal, min 2.92mm, max 3.40mm
    - 4mm nominal, min 3.78mm, max 4.19mm

Initial calculations

Valeri Makeev observed that with 500 mm spacer pitch 2 mm glass was bent to touch from Coulomb force. These calculations result in 0.76 mm deflection under those condition compared to 1mm reported. The precise voltage, edge effects, etc. from the test are not available.

spacer pitch	internal pressure in of	nominal thickness	Glass Stress	Glass Deflection	tensile only Adhesive
mm	water	mm	psi	mm	psi
100	2	2	107	3.57E-03	4
125	2	2	169	8.86E-03	4
150	2	2	244	1.86E-02	5
175	2	2	334	3.47E-02	6
200	2	2	437	5.95E-02	7
225	2	2	554	9.57E-02	8
250	2	2	686	1.46E-01	9
275	2	2	831	2.15E-01	10
300	2	2	990	3.05E-01	11
100	4	2	214	7.14E-03	7
125	4	2	337	1.77E-02	9
150	4	2	488	3.71E-02	11
175	4	2	667	6.93E-02	12
200	4	2	874	1.19E-01	14
100	8	2	428	1.43E-02	14
125	8	2	675	3.54E-02	18
150	8	2	977	7.43E-02	21
100	16	2	857	2.86E-02	28
100	2	3	41	8.36E-04	4
125	2	3	64	2.08E-03	4
150	2	3	93	4.35E-03	5
175	2	3	127	8.12E-03	6

200	2	3	166	1.39E-02	7
225	2	3	211	2.24E-02	8
250	2	3	261	3.43E-02	9
275	2	3	316	5.04E-02	10
300	2	3	376	7.15E-02	11
325	2	3	442	9.87E-02	12
350	2	3	513	1.33E-01	13
100	4	3	81	1.67E-03	7
125	4	3	128	4.15E-03	9
150	4	3	186	8.70E-03	11
175	4	3	254	1.62E-02	12
200	4	3	332	2.79E-02	14
225	4	3	421	4.49E-02	16
250	4	3	521	6.86E-02	18
275	4	3	632	1.01E-01	20
300	4	3	753	1.43E-01	21
325	4	3	884	1.97E-01	23
100	8	3	163	3.35E-03	14
125	8	3	256	8.30E-03	18
150	8	3	371	1.74E-02	21
175	8	3	507	3.25E-02	25
200	8	3	664	5.57E-02	29
225	8	3	843	8.97E-02	32
100	16	3	326	6.69E-03	28
125	16	3	513	1.66E-02	35
150	16	3	742	3.48E-02	43
100	32	3	651	1.34E-02	56
100	2	4	24	3.86E-04	4
125	2	4	38	9.57E-04	4
150	2	4	55	2.01E-03	5
175	2	4	76	3.74E-03	6
200	2	4	99	6.42E-03	7
225	2	4	126	1.03E-02	8
250	2	4	156	1.58E-02	9
275	2	4	188	2.32E-02	10
300	2	4	225	3.30E-02	11
325	2	4	264	4.55E-02	12
350	2	4	306	6.13E-02	13
100	4	4	49	7.71E-04	7
125	4	4	76	1.91E-03	9
150	4	4	111	4.01E-03	11
175	4	4	151	7.49E-03	12
200	4	4	198	1.28E-02	14
225	4	4	251	2.07E-02	16
250	4	4	311	3.16E-02	18
275	4	4	377	4.64E-02	20
300	4	4	449	6.59E-02	21
325	4	4	528	9.10E-02	23
350	4	4	612	1.23E-01	25
100	8	4	97	1.54E-03	14

125	8	4	153	3.83E-03	18
150	8	4	222	8.02E-03	21
175	8	4	303	1.50E-02	25
200	8	4	396	2.57E-02	29
225	8	4	503	4.13E-02	32
250	8	4	622	6.32E-02	36
275	8	4	754	9.29E-02	39
300	8	4	898	1.32E-01	43
100	16	4	194	3.08E-03	28
125	16	4	306	7.65E-03	35
150	16	4	443	1.60E-02	43
175	16	4	605	3.00E-02	50
200	16	4	793	5.14E-02	57
100	32	4	388	6.17E-03	56
125	32	4	612	1.53E-02	71
150	32	4	886	3.21E-02	85
100	64	4	777	1.23E-02	113

Finite Element Analysis

From these initial calculations a selection was made with 3 mm nominal thickness, 200 mm spacer pitch and 8 inches of water pressure. A finite element analysis was then made for this one case to more accurately find the stress and deflections. The three dimensional model included end effects.

The FEA model agrees with the glass stress from the initial calculations. It did not show a peel stress problem with the adhesive. It did show a stress concentration under 1000 psi at the end of the spacers which would be acceptable. However the model needs to be calibrated with physical data. Testing will be done later this year.